Office of Naval Research International Field Office

Report

Japan's primary high-speed vessel program:
The Techno Superliner

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Keywords

High-speed ships, sealift, naval architecture, marine engineering, ship design, shipbuilding.

Summary

The current major project on high-speed ships in Japan is an effort to design and build a large commercial Techno Superliner passenger/cargo ferry with the following basic characteristics:

- Type: Surface effect ship (SES)
- Length: 140m
- Payload: 725 passengers plus 210 tons of cargo
- Speed: approx. 38 knots

The vessel is scheduled to be delivered in 2005 and is intended for service between Tokyo and the Ogasawara (Bonin) Islands about 1,000 km south. The design and construction of this vessel will represent the culmination of a research-design-build program that has been underway since 1989.

The Techno Superliner initiative: Three phases

Many research and development projects on high-speed vessels have been pursued in Japan in recent decades. Since 1989 the primary object of much of this research has been the development of a commercially viable high-speed ship called the Techno Superliner or TSL. By looking at the top-level milestones for this initiative, three basic phases to the work can be identified:

- **Phase I: 1989-1995**
  R&D carried out by the Technological Research Association of TSL.
  Construction of a half-size test ship.

- **Phase II: 1996-2002**
  Operational experience gained with the half-size test ship.
  Investigation of commercial scenarios for the full-size TSL.

- **Phase III: 2002-2005**
  Design, construction, and commercial operation of the full-size TSL.

These phases, and the general workflow associated with each, are mapped out in Fig. 1.[1]

[1] Our 'three phase' nomenclature is an explanatory aid, which reflects actual workflow but is not the official program management terminology.

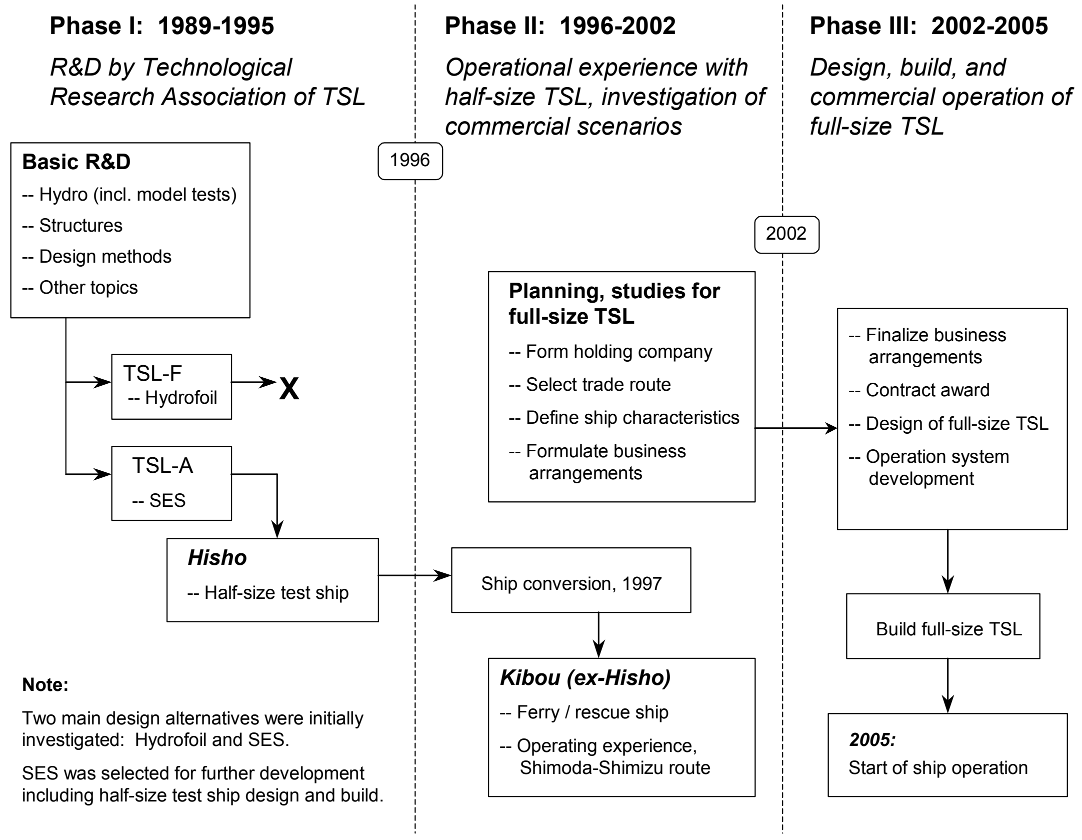

Fig. 1: The Techno Superliner initiative: General workflow.

Further description of each phase

Phase I: R&D carried out by the Technological Research Association of TSL, construction of half-size test ship.

By the late 1980's, the Japanese shipbuilding industry and government were working on new shipping concepts to alleviate infrastructure problems such as severe road congestion in the coastal areas of Japan. The shipbuilders were also interested in boosting their business edge through the development and commercial exploitation of technologically-driven innovation. High-speed vessels represented an attractive challenge and so a plan was formulated whose long-term goal was to realize a commercially viable ship having the following characteristics:

- 50 knot speed,
- 1000 ton payload,
- 500 n.m. cruising range, and
- Good seaworthiness in rough seas.

This set of requirements drove the basic flow of research work. However, before the final (full size) vessel could be designed and built it was necessary to gain knowledge and experience with a smaller vehicle. Preliminary research and development was conducted for two types of ship: TSL-A (surface effect ship) and TSL-F (hydrofoil). The TSL-A type (SES) was selected for further development and testing. For the culmination of Phase I, an experimental prototype about half the size of the target characteristics shown above was designed – the vessel was named *Hisho* (see Table 1). The *Hisho* was developed and constructed jointly by Mitsui Engineering & Shipbuilding Co. and Mitsubishi Heavy Industries and comprehensive sea trials were carried out in 1995.

Table 1: Particulars of TSL-A *Hisho*
(The half-size test ship built in Phase I)

L_{OA} :	70.0m
Breadth:	18.6m
Depth:	7.5m
Draft:	3.5m (off air-cushion)
	1.1m (on air cushion)
Payload:	200 tons
Speed :	50 knots
Propulsion engine:	16,000ps gas turbine x 2
Number of water jet pumps:	2
Number of lift fans:	8

The major test results obtained with the *Hisho* in 1995 were:

- Speed of 54.25 knots was achieved.
- A method of ship speed prediction was established.
- It was estimated that the full-size TSL would be seaworthy at sea state 6 with a speed reduction of 10-15%.

The extensive sea trials proved the integrity of each subsystem such as hull structure, skirt, fin control system and propulsion system. Since the experimental ship was designed to transport containers, a quick loading/unloading system for containers was developed and tested. It was designed to be capable of loading and unloading horizontally 150 twenty-foot containers in two tiers on the deck within one hour. The new system was proven to satisfy the requirement.

After the tests, the *Hisho* spent about four months on a series of experimental voyages, visiting many ports in Japan. Rough seas of up to typhoon magnitude were encountered and the ship's heavy weather performance turned out to be even better than anticipated.

Phase II: Operational experience gained with the half-size TSL and investigation of commercial scenarios for the full-size TSL.

Operational experience with half-size TSL:

After completion of the test program, the half-size TSL *Hisho* was converted to serve as a ferry and rescue ship. The vessel was renamed the *Kibou* and is now owned by the government of Shizuoka Prefecture. It has been in weekend service between Shimoda and Shimizu (94 km) since June 1997, accumulating further operational experience. The *Kibou* can carry 260 passengers and 30 passenger cars (or 5 large buses plus 10 passenger cars) at a speed of 40+ knots. In October 1999 we rode the TSL *Kibou* on one of its Shimoda-Shimizu trips. During our passage we experienced a speed of 42 knots in sea state 5 without uncomfortable motion.

Fig. 1: Half-size TSL *Kibou*

Investigation of commercial scenarios for the full-size TSL:

As part of Phase II, the Japanese government studied various strategies for the commercialization of the final, full-size TSL for the broader transportation market. Several potential trade routes were studied as well as approaches for mitigating the risks faced by potential commercial operators. Some of the original transportation concepts, such as the coastal Japan trade, did not prove viable. But the Tokyo municipal government, whose jurisdiction includes the Ogasawara Islands located about 1,000 km to the south, picked up on the TSL as a way to provide improved access to these rather isolated Pacific islands. A conventional ferry provides transportation to and from these islands, but the passage takes over 25 hours one way. Faster service would go a long way towards promoting economic development. The planned full-size TSL could reduce transit time from 25 to 16 hours. Furthermore, as the construction of an airport has been ruled out due to environmental concerns, the high-speed ship is the only realistic option. So the Tokyo municipal government was brought on board as a customer.

Because of the new technologies embodied in the TSL, the business risk is higher than for an ordinary commercial ship acquisition so in December 2000 the Japanese government supported the stand-up of a new holding company which will underwrite certain of the risks and costs associated with TSL operations. With this holding company in place, the ship operator will charter the TSL vessel rather than purchasing it. The TSL holding company will provide technical support by developing an operations and maintenance management system.

Phase III: Detail design, construction, and commercial operation of a full-size TSL.

In this phase, expected to start this year, the final roles and responsibilities to be assumed by the owner (the TSL holding company), the builders, and the national and Tokyo municipal governments will be finalized. The ship will be designed, built, and in 2005 will enter service. The tentative particulars of the new full-size TSL vessel are shown in Table 2 (next section).

Discussion and assessment

As more details on the TSL program are expected later this year, a more specific discussion may be possible in a future report. In the meantime, however, we can offer some observations about the TSL, its intended performance, and how the TSL program may play an important role in the future of high speed naval design.

The TSL program: SES concept formulation, design, and in-service experience

Perhaps the key attraction of the TSL program is that it represents an ambitious development of the surface effect ship (SES) concept. The basic limitation in high-speed displacement vessel design arises from the need to expend considerable power in overcoming wave-making resistance, which increases sharply beyond a certain point. Above a certain threshold speed, the speed/power curve rises so steeply that any desired increase in speed would require a prohibitive power increase.

The SES concept attacks this problem by reducing wave-making resistance through air lift. It is generally recognized that beyond about 50 knots or so, the SES's speed/power curve is not as steep as that of the displacement hull form. This means that as future power plants are developed having higher output and efficiency for a given weight, the SES may become feasible for large, extremely fast ships before the displacement hull does.

Science & Technology management and the TSL program

Earlier improvements in the power-to-weight ratio of marine power plants led to the development and proliferation of the modern high-speed planing motorboat in the 1930's.[2] It is not entirely unrealistic to envision that future power plant development may make the SES an attractive alternative in the future as well.

Therefore, although commercial operation is intended, the TSL's real value is as a key marine technology demonstration platform. The full-size TSL is intended to be basically a commercialized test-bed. A direct analogy: Toyota's hybrid electric/gasoline powered automobile, the *Prius*. This car is 'commercially feasible' in the sense that Toyota does sell them and they are indeed operated in the real world by ordinary drivers. But the *Prius* was not designed to represent today's most effective automotive transportation package. Instead, it is a technology demonstrator and a platform for gaining technological and operational experience that will be capitalized on in the future.

The *Prius* and the Techno Superliner are excellent examples of strategic investment in techno/economic real options.

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[2] Comstock J. P., ed., *Principles of Naval Architecture* (New York: SNAME, 1967, p. 365).

The TSL and the Australian fast ferries

The performance spec for the full-size TSL is not too different from that of the highly successful Incat and Austal catamaran ferries.[3] Some comparative particulars of the TSL and Incat's *Joint Venture* HSV-X1 (currently on charter to the U.S. military) are shown in Table 2. The Australian vessels are attractive designs and are very effective. But although they have advanced hull forms, they are displacement-type vessels and are therefore their future development is subject to the limitations of their speed-power curve above around 50 knots or so (see above discussion).

What does the future hold in terms of extremely high-speed vessels above the approx. 50 knot point? SES's? Foil borne? A new type of displacement form? Some sort of hybrid? No one can predict with certainty, but this should be a very challenging area of naval architecture for some time yet.

Table 2: Full size TSL, Incat HSV-X1

	TSL (tentative)	HSV-X1
L_{OA}	140m	95m
Breadth	29.8m	26.6m
Payload	725 passengers plus 210 tons cargo	363 persons incl. crew plus vehicle deck and helo deck
Speed	approx. 38 knots	approx. 38 knots
Range	approx. 2,200 km	2,055 km at 35 knots

Notes:

1. TSL data source: Nippon Kaiji Press (Jan. 1, 2002).
2. HSV-X1 data source: *Incat: The Magazine* (Vol. 3, Issue 13, 2001, pp. 12-13).
3. The HSV-X1 was launched in 1998 and converted to its current configuration in Sept. 2001.
4. Speed and range are sensitive to loading condition and sea state.

References to previous ONR IFO reports on the Techno Superliner

- November 1999:
  An article in *Shipbuilding and Ocean Technology: Asia-Pacific Region* No. 3.
- October 1999:
  A trip report describing a passage on board the half-size TSL test ship *Kibou*.
- July 1999:
  An article in *Shipbuilding and Ocean Technology: Asia-Pacific Region* No. 2.

[3] See our article in Newsletter #5, May 2000 ("Austal Ships and Incat Australia: Shipbuilding Competitiveness via Product Differentiation and Focus.")

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